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SOME CONSIDERATIONS ON PLASTIC MATERIALS FOR USE AS
SAFETY CONTAINERS


U. S. NAVAL PROPELLANT PLANT INDIAN HEAD, MARYLAND

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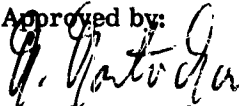
FOREWORD

The work described in this report was funded by the Bureau of Naval Weapons under Task Assignment RMMP-22-004/286-1/F009-06-01. The data are as of 30 November 1962 and are described on laboratory notebook pages 54001-54060 and 70351-70423.



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ABSTRACT

Developmental studies were made with polyurethane containers. The effects of material properties, shape and size of both inner vials and containers, and the shock attenuation of the container material were investigated. Various materials were evaluated as possible candidates for fabricating the containers.

Polyethylene containers, to safely hold comparatively large loads of explosive materials, have been developed and investigated. A 10-cm-diameter container can easily withstand the explosion of 15 g of nitroglycerin, and a 32-cm-diameter container can withstand an explosion of 500 g of nitroglycerin. The smaller container weighs 0.775 kilogram and can easily be handled by one hand; the larger container weighs less than 22 kilograms and is easily made portable with carrying handles or by transporting in a cart.

SOME CONSIDERATIONS ON PLASTIC MATERIALS FOR USE AS SAFETY CONTAINERS

The E. I. du Pont de Nemours and Company has developed a polyurethane "tote barricade" to protect personnel, hand-carrying sensitive material, from the effects of an accidental explosion. These barricades withstood the explosion of 2 g of nitroglycerin. Inspired by Du Pont, this study was initiated to develop an explosive safety container able to withstand the explosion of higher loads of nitroglycerin than 2 g and to investigate the behavior of the container during an explosion.

To be detonation-safe, the sample container was required to withstand at least a minimum load of explosive material. To be additionally safe, the sample container (Figure 1) was to be fabricated from a material which would form harmless fragments upon break-up from a maximum load detonation. In other words, the material had to be one which would not form fragments or one which would form fragments harmless to personnel.



FIGURE 1. POLYURETHANE SAFETY CONTAINER OF 8.1-CM DIAMETER WITH
INSERTED POLYETHYLENE VIAL OF 1.25-CM DIAMETER

Initially, an exploratory study was made with polyurethane containers. This material was chosen because (1) it was available, (2) it met most of the prerequisites for a good safety container, and (3) it was a transparent material so that the effects of explosion could be observed throughout the structure. From the results of this study, other investigations concerning the improvement of the polyurethane containers were carried out. Various other materials were analyzed for possible use for containers.

EXPERIMENTAL METHODS

Polyurethane sample containers, 8.1 cm in diameter, were filled with various loads of nitroglycerin. During this investigation, nitroglycerin was employed as the standard explosive to determine maximum safe loads for all sample containers studied. A S-67 Du Pont squib or a 70-mg cyanuric triazide initiator jolted with 12.5 joules of electric current was used to explode the nitroglycerin. The resulting explosion phenomena of the nitroglycerin and the effects on the container were recorded.

High-Speed Framing Camera:

This instrument takes 25 pictures of events at rates of up to 1.2×10^6 frames/second. Using proper lighting techniques, it was possible to trace the shock wave through the container and to observe the degradation and mechanical failure of the polyurethane.

High-Speed Velocity Recorder:

Accurate measurements of the explosion velocity of nitroglycerin were made with the velocity recorder. The setup and a typical shock-wave trace are shown in Figures 2 and 3. In order to trace the passage of a shock wave in an inert transparent material like polyurethane, an exploding wire (in a capillary tube) was used as backlight. (1,2,3)

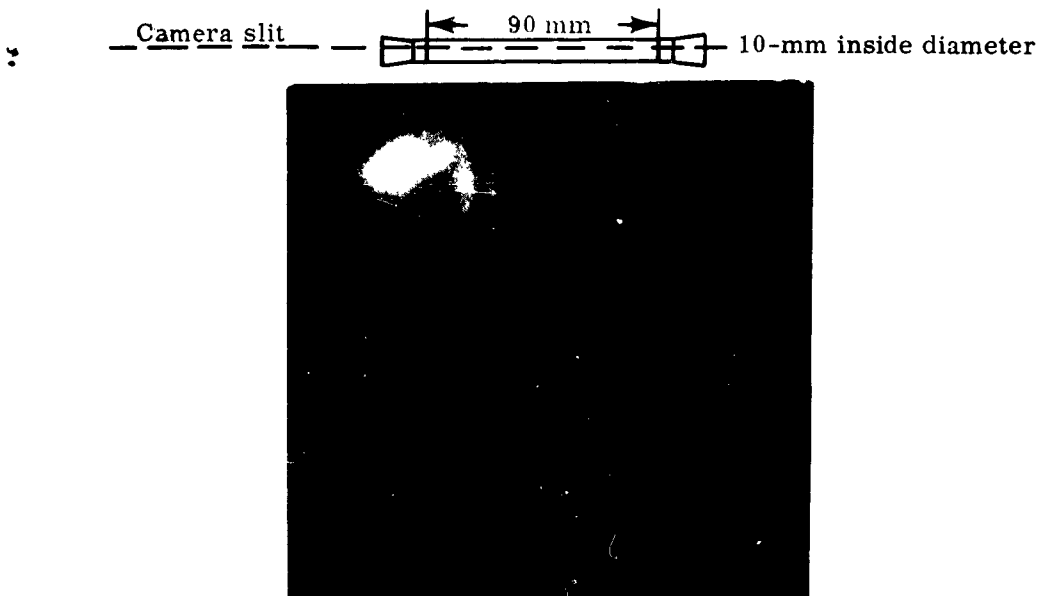


FIGURE 2. ASSEMBLY FOR THE MEASUREMENT OF "DETONATION" VELOCITY OF NITROGLYCERIN (Writing speed: 0.3192 mm/ μ sec)



FIGURE 3. TRACE OF A SHOCK WAVE TRANSMITTED THROUGH A
POLYURETHANE SAFETY CONTAINER BY THE EXPLOSION OF
5-g NITROGLYCERIN USING AN ELECTRIC S-67 SQUIB AS
DETONATOR (Writing speed: 0.6384 mm/ μ sec)

RESULTS

Polyurethane explosive sample containers were fabricated with 40% toluene diisocyanate (80/20 of 2,4-/2,6-)¹ and 60% castor oil.

As an initial step, the sample containers were filled with a 1- to 5-g load of nitroglycerin. It was decided to use a small cyanuric triazide squib (50-70 mg) with 12.5 joules of electric energy to set off the nitroglycerin. It was assumed that any accidental detonation would be initiated by a relatively small quantity of energy in the form of shock, electric-static energy, local heating effects, etc.

As each sample container loaded with nitroglycerin was set off, high-speed framing-sequence photographs of each shot were made. The sample containers and the photographs were examined after the explosion. Observations were made concerning the nitroglycerin explosion phenomena and the physical structure of the container.

Nitroglycerin "Explosion" Phenomena:

As expected, the "detonation" was of low order. The nitroglycerin reacted in a few microseconds within the short confines of the vial. This low-order reaction will henceforth be termed an "explosion" rather than a "detonation."

Physical Structure of Safety Container:

During an explosion, there are two possible destructive forces acting on the container—the shock wave, and the outward pressure exerted by the hot gases from the nitroglycerin explosion. The containers begin to bulge within a few microseconds after the initiation of the nitroglycerin, and fracture lines start to form soon after—the time interval being dependent upon the nitroglycerin load. Figures 4 and 5 are selected framing sequences for a 1- and a 5-g load of nitroglycerin.

Table I gives the tensile strengths and elongation of polyurethane and polyethylene tested at a crosshead rate of 20 in/min and at various temperatures.

The characteristic behavior of a polymer subjected to increasing strain rates is analogous to its behavior under decreasing temperature conditions. The polyurethane is exposed to strain rates of 25×10^6 in/min; therefore, the elongation of polyurethane must be very small and the tensile strength relatively high.

¹ Formulation developed by J. H. Pollack, U. S. Naval Propellant Plant.

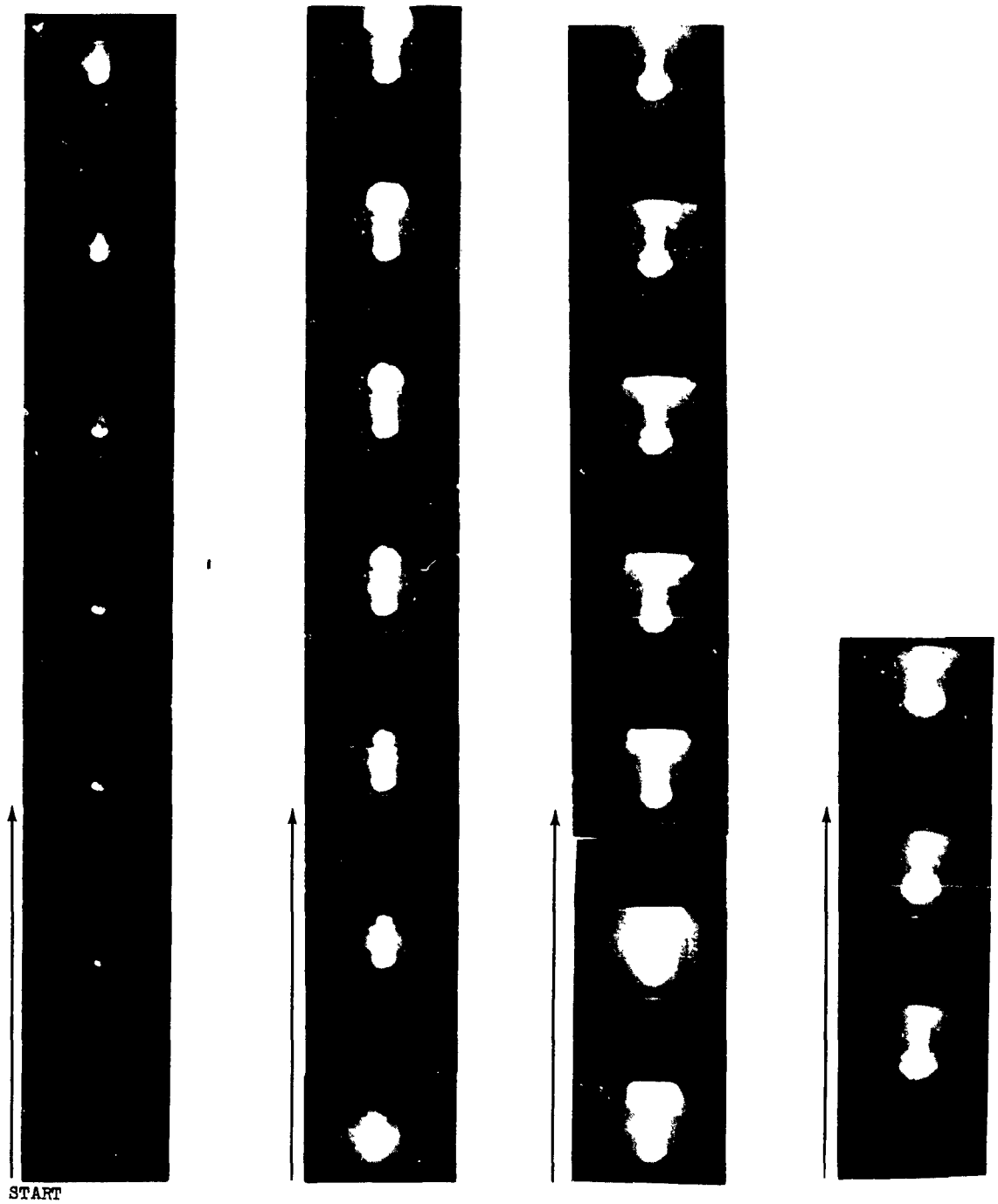


FIGURE 4. EXPLOSION OF NITROGLYCERIN (1-g) IN A
POLYURETHANE SAFETY CONTAINER (Interframe time: 4.2 μ sec)

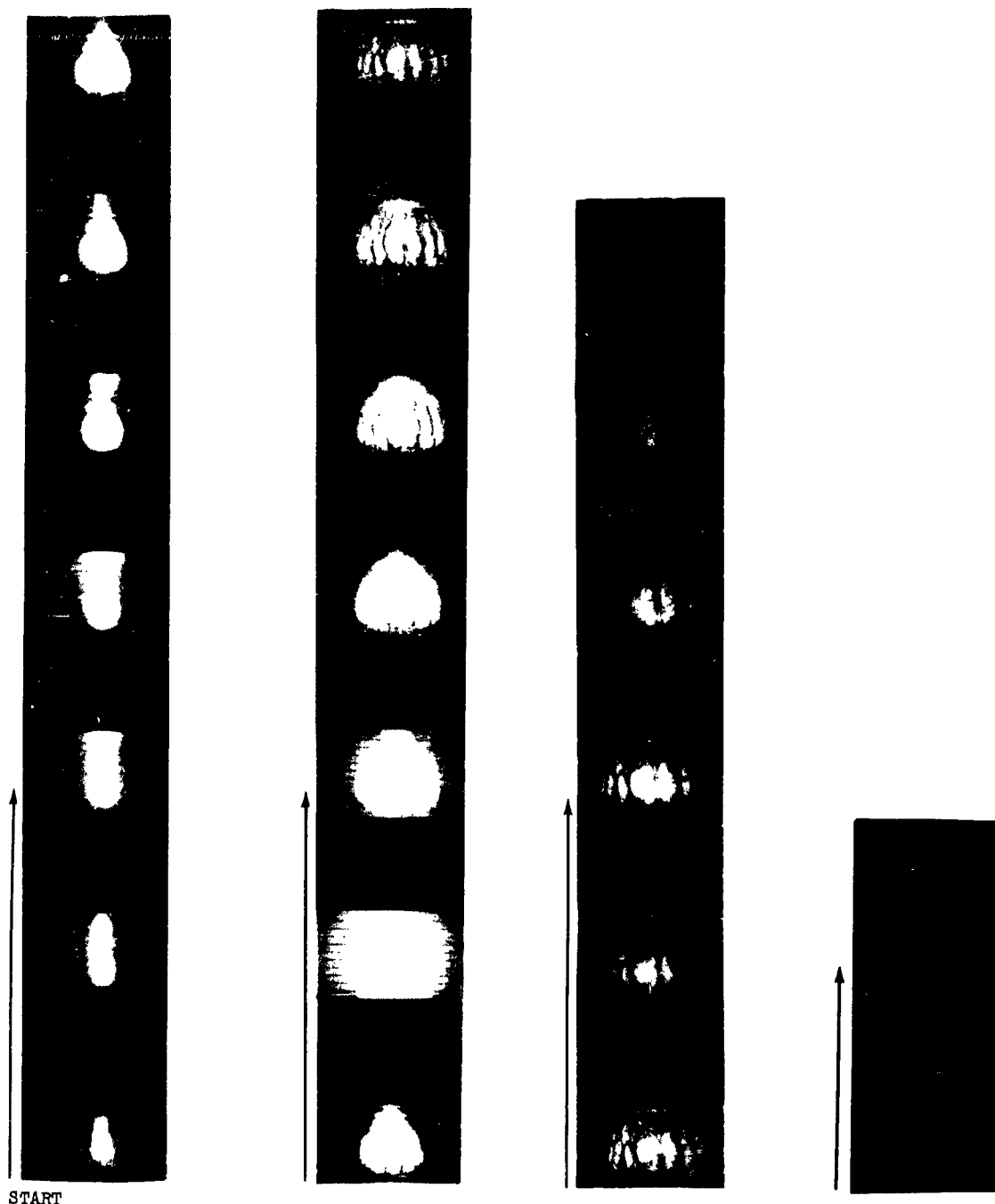


FIGURE 5. EXPLOSION OF NITROGLYCERIN (5-g) IN A
POLYURETHANE SAFETY CONTAINER (Interframe time: 16 μ sec)

Table I

TENSILE STRENGTH AT 20 INCHES/MINUTE CROSSHEAD RATE

Test temperature (°C)	Polyurethane		Polyethylene	
	Tensile strength ¹ (psi)	Elongation ² (%)	Tensile strength ¹ (psi)	Elongation ² (%)
25	203	126	2040	592
0	800	280	1840	580
-25	3622	236	-	-
-50	7133	12.3	-	-

¹Tensile strength is based on original specimen area.

²Elongation is calculated using an effective gage length of 1.7 inches with ASTM D 412-51T DIE C.

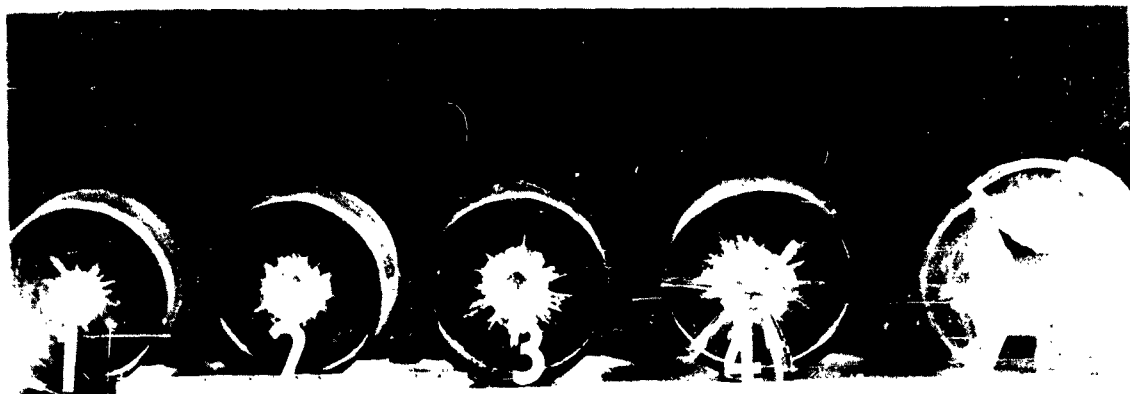
The container elongates along the circumference as the hot detonation gases expand. The inner circumference, or wall of the container, will elongate at a much higher rate for a given radial expansion of the inner hole than a zone farther from the center periphery. Therefore, the polyurethane will start to fracture from the inner wall when maximum elongation of the material is reached.

As the explosion of the nitroglycerin proceeds, the gases will be ejected from the top of the open vial and the gas pressure will bulge the walls of the sample container. These two actions will cause the inner pressure to decrease with time. The fracture of the walls will continue until the forces acting upon the polyurethane, at that point, approach the maximum tensile strength and the maximum elongation point of the material. At this point, as the inner expanding forces are continually decreasing, the fracture will stop. Figure 6 shows sample containers after various loads of nitroglycerin have been exploded in them. Figure 7 is a plot of radial fracture line length versus the nitroglycerin load. The maximum nitroglycerin load limit for this polyurethane container is 3.5 g.

Strengthening and Modifying the Polyurethane Safety Container:

From this preliminary and exploratory study, the following question concerning the most favorable characteristics for an explosive safety container arose. Would it be possible to strengthen or modify the polyurethane container so that it could handle larger loads of explosive materials? The following modifications to the basic container were innovated and the containers were tested with 5 g of nitroglycerin.

Wrapping or Encasing the Container with Strong Materials: The total strength of the container can be increased by wrapping it with a strong cord or wire, or by encasing it with a strong metal. The polyurethane, around the central vial, is prestressed by the compressive forces generated by the expanding explosion gases and, therefore, is



1 g 1.5 g Top view
2 g 4 g 5 g



Side view

FIGURE 6. POLYURETHANE SAFETY CONTAINER AFTER TESTING WITH
VARIOUS LOADS OF NITROGLYCERIN USING APPROXIMATELY
50 mg OF CYANURIC TRIAZIDE AND AN EXPLODING WIRE
(5000 v, 3μ F) AS DETONATOR

RESEARCH AND DEVELOPMENT DEPARTMENT

**NavWeps Report 8030
Technical Report 130**

15 April 1963

**SOME CONSIDERATIONS ON PLASTIC MATERIALS
FOR USE AS SAFETY CONTAINERS**

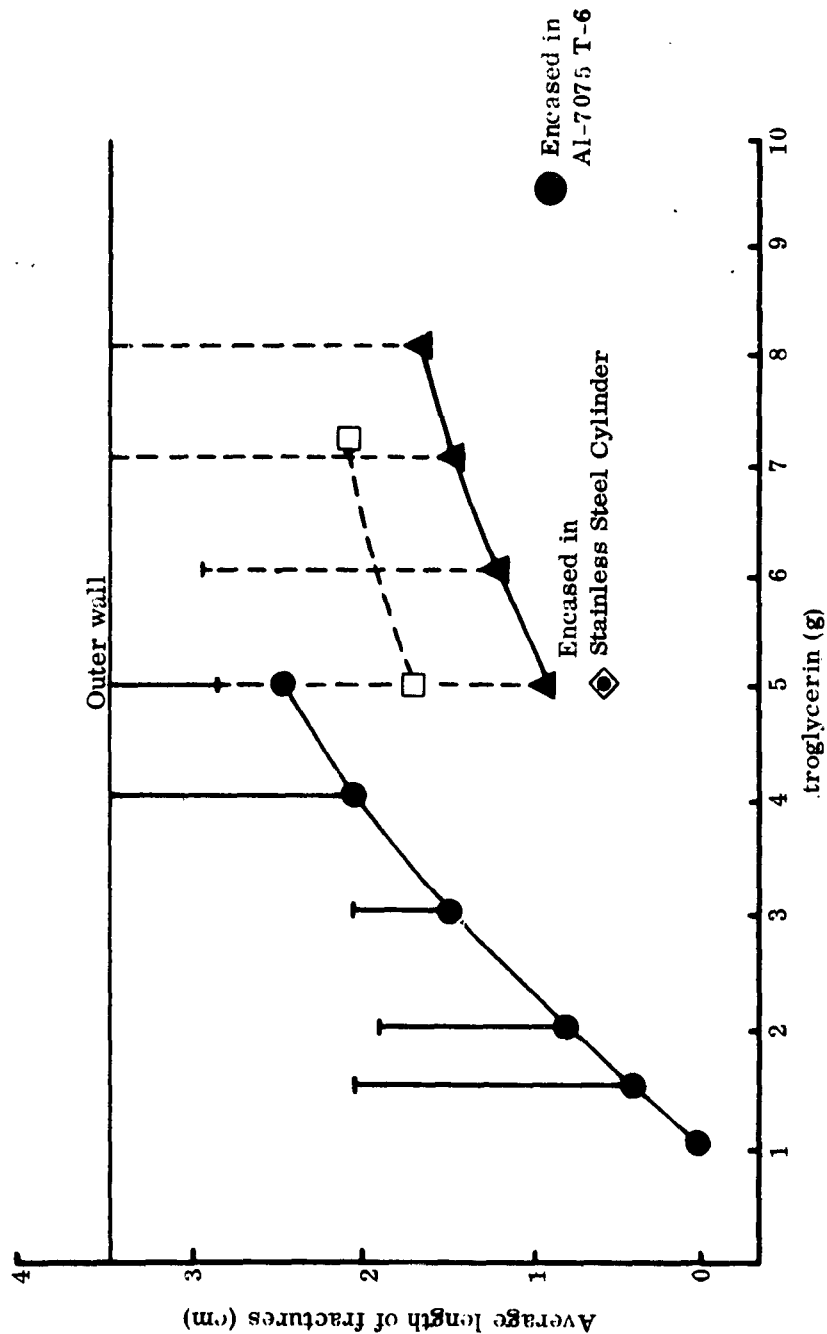
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● Without strengthening material.
▲ Strengthened with 3 layers of 120-lb test Dacron line.
□ Strengthened with 1 layer nichromwire 101-lb test.
FIGURE 7. FRACTURES OF EXPLOSIVE POLYURETHANE SAFETY CONTAINER
CAUSED BY EXPLODING NITROGLYCERIN

prevented from expanding normally. Figure 7 also shows the increased load-capacity for containers wrapped with 120-lb-test Dacron line and 101-lb-test nichrome wire; the Dacron-wrapped container was able to withstand a load of 8 g of nitroglycerin. Figure 8 is a picture of these containers and also one of an aluminum-encased polyurethane container after explosive testing. In order to see the damage on the containers, the strengthening material was removed after the explosion. Container 1 was strengthened with 3 layers of Dacron fishing cord, 130-lb test and withstood the explosion of 8-g nitroglycerin, and container 2 was strengthened with an aluminum encasing of 125-mm wall thickness and withstood the explosion of 9.5-g nitroglycerin. The third container was fabricated from aluminum (AL-7075-T-6) and withstood the explosion of 10-g nitroglycerin with very little change in the outside dimensions. Stainless-steel-walled containers (1.8-mm thick) were able to withstand the explosion of 5-g loads, but the steel castings were deformed to some extent.

Increasing Tensile Strength of Polyurethane Container by Addition of Strong Fibers:

To increase the tensile strength of the material, various amounts of glass wool, glass fiber fabric, and nylon fabric were added in a spiral pattern around the central vial. Three sample containers, with each of the above mentioned fiber and fabric additions, were tested with 5 g of nitroglycerin. The results showed that the improvements in strength were not enough to warrant further investigation along this line.

Improvement of the Material Properties of the Zone Surrounding the Central Vial:

When a material undergoes rapid strain, it behaves as if it were at a much lower temperature. The polyurethane's tensile strength increases and its percentage of elongation, before break, decreases (Table I) with more rapid strain rates.

Attempts were made to improve the elongation and cold-flow properties of the zone surrounding the central vial. This was done by inserting various materials, e.g., natural rubber, Wood's metal, etc., in this zone. There was some improvement in the load capacity; however, the total strength of the containers was lessened by the substitution of the polyurethane by the low-strength (but good cold-flow property) material.

Interruption of the Propagation of Fracture Lines and of Shock Wave: When a material is under stress, fractures in the structure cause an over-all loss of strength. By interrupting the propagation of the fracture from the center, the container should be able to withstand the explosions of larger loads of nitroglycerin. With this idea in mind, containers were fabricated employing the two methods listed.

(1) An 8-cm-wide strip of 0.15-cm-thick polyurethane was wound around a 12.5-mm (inner diameter) vial until an 8-cm-diameter container was formed. A 12.5-mm plug was inserted below the vial.

(2) Glass and polyethylene beakers and vials were positioned concentrically around the central vial, and polyurethane was molded around the tubes and beakers.

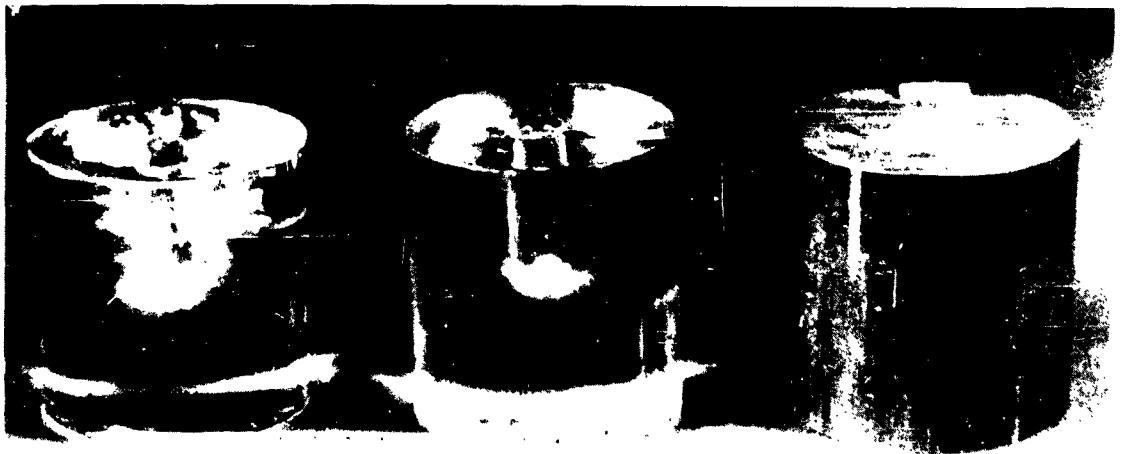


8 g

9.5 g

Top view

10 g



Side view

FIGURE 8. POLYURETHANE CONTAINER STRENGTHENED WITH (1) 3 LAYERS DACRON FISHING CORD 130-lb TEST AFTER THE EXPLOSION OF 8-g NITROGLYCERIN, (2) ALUMINUM OUTER WALLS OF 12.5-mm THICKNESS AFTER THE EXPLOSION OF 9.5-g NITROGLYCERIN, AND (3) ALUMINUM (7075-T-6) CONTAINER AFTER THE EXPLOSION OF 10-g NITROGLYCERIN

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As a shock wave is partially reflected and attenuated at each interface or inhomogeneity of a material, the many interfaces created by the separated material should also attenuate the shock wave as it passes through the container. In all probability, the poor bond between the polyurethane layers of the first type container and between the polyethylene and polyurethane of the second type container weakened the structure of the containers as they did not withstand the explosion of 5 g of nitroglycerin. However, there were indications that the polyethylene interfaces prevented propagation of fractures and that there seemed to be less damage done to the polyethylene-beaker containers.

To improve the shock attenuating qualities of the polyurethane, containers of the following types were fabricated and tested with 5 g of nitroglycerin:

(1) Foamed polyurethane. (Air bubbles are good shock attenuators—for example, in underwater explosions the measuring equipment is protected by surrounding it with a veil of air bubbles.^(4, 5) A large part of the shock energy is annihilated by the air bubbles.)

(2) Circular air gaps were put in the polyurethane around the central vial.

(3) Calcium sulfate was inserted around the central vial of the container. (Calcium sulfate has proved very effective as a blast shield in our studies.)

In all of these containers, the structure was weakened to such an extent by the modifications to the container that they were fragmented to many pieces by the explosion of the nitroglycerin.

Effect of Vial Material, Size, and Shape on Over-All Container Strength:

Vial Material: The results from the first explosions on containers fabricated with glass vial inserts indicated that the fracture lines in the polyurethane seemed to originate from the fracture lines in the central glass vial. To control this, vials of various materials were inserted into the polyurethane containers. Besides glass, polyethylene of medium density (with its high percentage of elongation and good tensile strength) and polypropylene of high density were used as vial materials. High-density polypropylene has excellent tensile strength but a low percentage of elongation. The amount of fracture formation in the polyethylene vial container, when exploded with nitroglycerin, was considerably less than in either the polypropylene or in the glass.

Critical Diameter of the Vial Inserted in the Safety Container: The effect of the explosion velocity on the investigated safety container can be compared to the influence of the detonation velocity on the Trauzl-Block. As high pressures in the detonation front correspond to high-detonation velocities, the detonation velocity must be taken into account. These various pressures are caused by the process of the reaction in the detonation zone. At high-detonation velocities, the chemical reaction has almost finished

within the detonation zone. This stipulates very high pressures over a very short period of time. At low-detonation velocity, only part of the chemical reaction takes place within the detonation zone; there is a chemical reaction behind the detonation front causing a lower pressure which acts over a longer period of time.

Nitroglycerin, as with many other explosives, has a low- and a high-order detonation velocity. Charge diameter and length, chemical characteristics, physical state and condition of the explosive, and the amount of detonator determine the detonation velocities of the nitroglycerin. Several investigators^(6,7) have studied the above parameters for the detonation of nitroglycerin and have established a high-order (7800 m/sec) and a low-order (2200 m/sec) detonation velocity. However, there seems to be little literature⁽⁸⁾ available on explosion velocities for small detonators and small-diameter charges. Below 100 mg of cyanuric triazide, the amount of detonator does not appreciably change the explosion velocity for a given diameter charge.

The reaction process for this explosion, with small detonators, seems to be an unsteady one. The initial explosion velocity is not sustained continuously. The nitroglycerin reacts in spots down the length of the vial as the shock front passes. As generally the detonation velocity is dependent upon the inner diameter of the tube containing the charge, it was considered essential, in the case of the small (8- or 10-cm diameter) safety container, to keep the vial diameter below the "critical diameter" for nitroglycerin initiated by small detonators. This "critical diameter" was measured at 12.5 mm. At this diameter the "explosion velocity, " 485 m/sec and lower for smaller diameter,¹ rises sharply and passes into a steady state detonation of high order with increasing diameter.

The ratio of the diameter of the vial to the length of the charge should be kept as high as possible so that a steady plane detonation wave cannot build up as easily as it would if the charge length were high compared to its diameter.

Influence of the Vial Shape: Changing the shape of the vial might enable the container to withstand the explosion of higher loads of nitroglycerin by either enclosing the blast or by directing most of the blast effect upward. Therefore, polyethylene vials of the shapes shown in Figure 9 were tested in molded polyurethane containers.

For a 5-g load of nitroglycerin no observable advantage in any specific shape was found. Since the cylindrical vial was the easiest to fabricate, all containers made later had vials of this shape.

¹Detailed information concerning this study will be presented in another report.

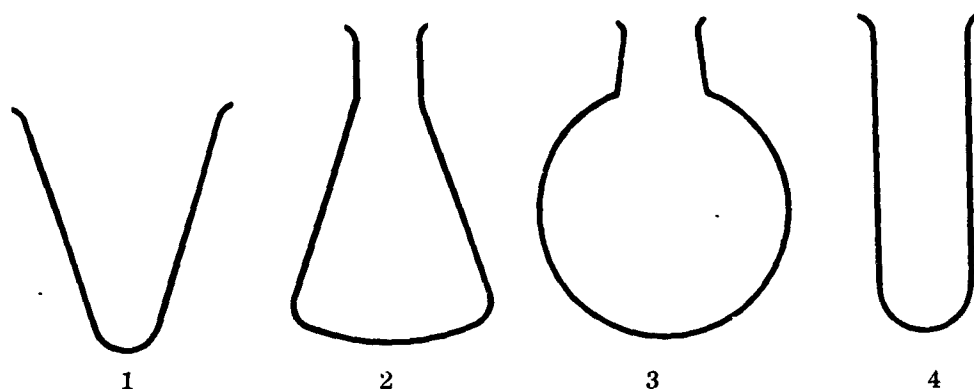


FIGURE 9. POLYETHYLENE VIALS OF VARIOUS SHAPES

Effect of Container Material and Size on Nitroglycerin Load Capacity:

Table II lists the various container materials which were tried. Containers with a 10-cm diameter were fabricated with 12.5-mm inside diameter holes and were exploded with 5 g of nitroglycerin. The aluminum and the medium-density polyethylene were the only containers to withstand the explosions. The aluminum container also withstood the explosion of 10 g of nitroglycerin with very little deformation, whether in inner or outer diameter.

The polyethylene container also withstood the explosion of 10 g of nitroglycerin with very little outside deformation (Figure 10). However, there was some deformation in both the inner and outer diameter with a 15-g load of nitroglycerin. The container sustained the detonation very well, and no fracture lines could be seen. It is evident that the expansion of the container hole, during the explosion, increases in depth and acts for a longer period of time on the bottom of the container than on the top of the container, as there the explosion gases can escape faster. The circles on Containers 1 and 2 show the original sizes of the holes before testing. For Container 3 the original size is drawn on the paper beside the tested container. To see better the bulging of the hole, this container was cut in two pieces.

A. Haid and H. Koenan⁽⁹⁻¹¹⁾ found that there was considerably less expansion of the container hole in using a high-density explosive in the Trauzl-Block than a low-density explosive. In testing the container, therefore, it should be taken into consideration that the bulging of the container would be influenced by the density of the explosive as well as by the amount.

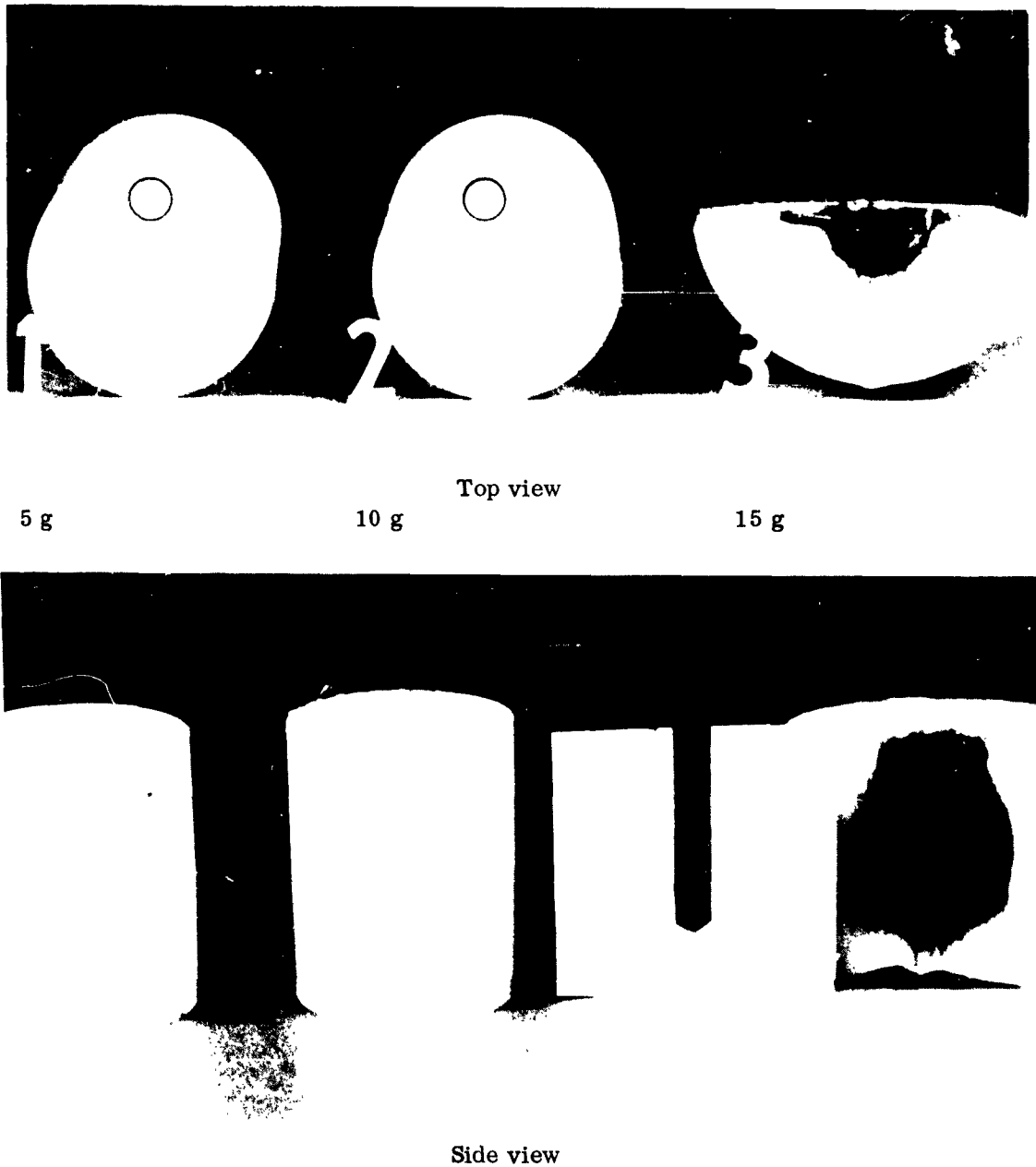


FIGURE 10. POLYETHYLENE SAFETY CONTAINER TESTED WITH
NITROGLYCERIN AND SQUIB A-67

Table II
LIST OF TESTED CONTAINER MATERIAL

Material	Container diameter (cm)	Hole diameter (cm)	Length of hole (cm)	Load of NG ¹ (g)
Polyurethane	8.1	1.25	4.0	(+) 3
Polyurethane strengthened with Dacron line	8.1	1.25	4.5	(+) 5
Polyurethane encased with steel	8.1	1.25	4.0	(+) 5
Polyurethane encased with aluminum	7.5	1.25	5.0	(+) 10
Polyethylene (medium density)	10.0	1.25	6.5	(+) 5
	10.0	1.25	7.0	(+) 10
	10.0	1.35	7.0	(+) 15
7075-T-6 aluminum	8.7	1.25	6.0	(+) 10
Nylon	10.1	1.25	5.0	(-) 5
Lucite	10.1	1.25	5.0	(-) 5
Polystyrene (crosslinked)	10.1	1.25	5.0	(-) 5
Polyvinyl chlorite	10.1	1.25	5.0	(-) 5
Polypropylene	10.1	1.25	5.0	(-) 5
Polyethylene	31.2	2.3	17.0	(+) 100
	31.2	3.06	22.1	(+) 250
	31.2	5.08	16.5	(+) 500
Teflon	10.1	1.25	6.0	(-) 10

¹ (+), Did withstand the explosion of the indicated amount of nitroglycerin; (-), did not withstand the explosion of the indicated amount of nitroglycerin.

Larger polyethylene containers, 30 cm in diameter, were tested with 100 and 250 g of nitroglycerin with very little outside deformation (some inner deformation). With a 500-g nitroglycerin load, the container was deformed to some extent (Figure 11) but sustained the detonation well. The circles on top of each container indicate the original sizes of the holes.

Polyethylene is a good material for explosive safety containers. It has the mechanical properties which suit the containment of an explosion. It has a high

percentage of elongation (up to 600%) before break and a relatively high tensile strength. It has very good cold-flow properties and deforms rather than fractures even at high strain rates.

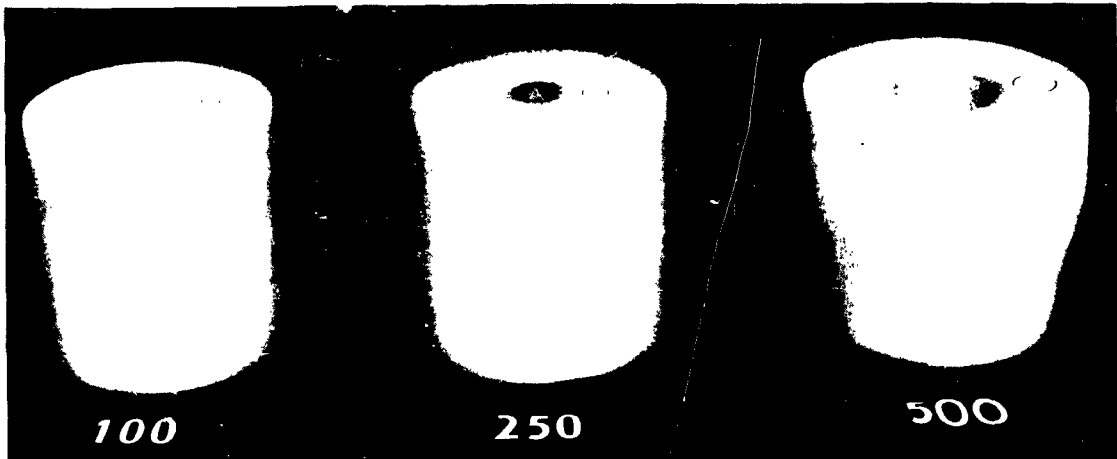


FIGURE 11. POLYETHYLENE SAFETY CONTAINERS AFTER THE EXPLOSION OF 100, 250, AND 500 g OF NITROGLYCERIN

Polyethylene has an arrangement of threadlike molecular carbon chains which is intermediate between those of the two conventional types; one the completely ordered or crystalline arrangement and the other a purely random or amorphous one. With these two arrangements, the polymer is both tough (from its crystalline qualities) and deformable (from its amorphous arrangement). Ordinary polyethylene has a high degree of crystallinity (around 60%-70%) as it has been estimated from X-ray studies. (12)

Explosions of high loads on polyethylene cause intermolecular slippage and result in permanent deformation. This slippage causes an improvement in the alignment of the molecular chains, particularly of the continuous molecular chain, and causes an increase in the proportion of crystallinity. This alignment plus this increase in crystallinity causes the material to exhibit enhanced strength. Therefore, after the polyethylene has become extended to some degree, the material becomes stronger. With a dropping inner pressure in the container vial, caused by the escape of hot gases from the open top and the expansion of the gases, the container can withstand the explosion of relatively large amounts of explosive material.

During most of this study, the nitroglycerin was initiated to a "low-order explosion" by a Du Pont S-67 squib jolted to détonation by passing 12.5 joules of electricity through it. This was done as any accidental explosion would be activated by a relatively small quantity of energy in the form of shock, electro-static discharge, local high temperature, etc.

It is of interest, however, to determine how the barricade withstood a high-order detonation. Figure 12 shows the 10.1 cm-diameter polyethylene explosive safety container after detonating 5 and 10 g of nitroglycerin to high order by a Hercules J-2 blasting cap (12.5 joules). The J-2 blasting cap has a 1-g pentolite load. The container withstood, essentially, the detonation of a 6-g load (5-g nitroglycerin and 1-g explosive in blasting cap) with some deformation. The 10-g nitroglycerin-loaded container (+ J-2 blasting cap) ruptured along the weaker side.

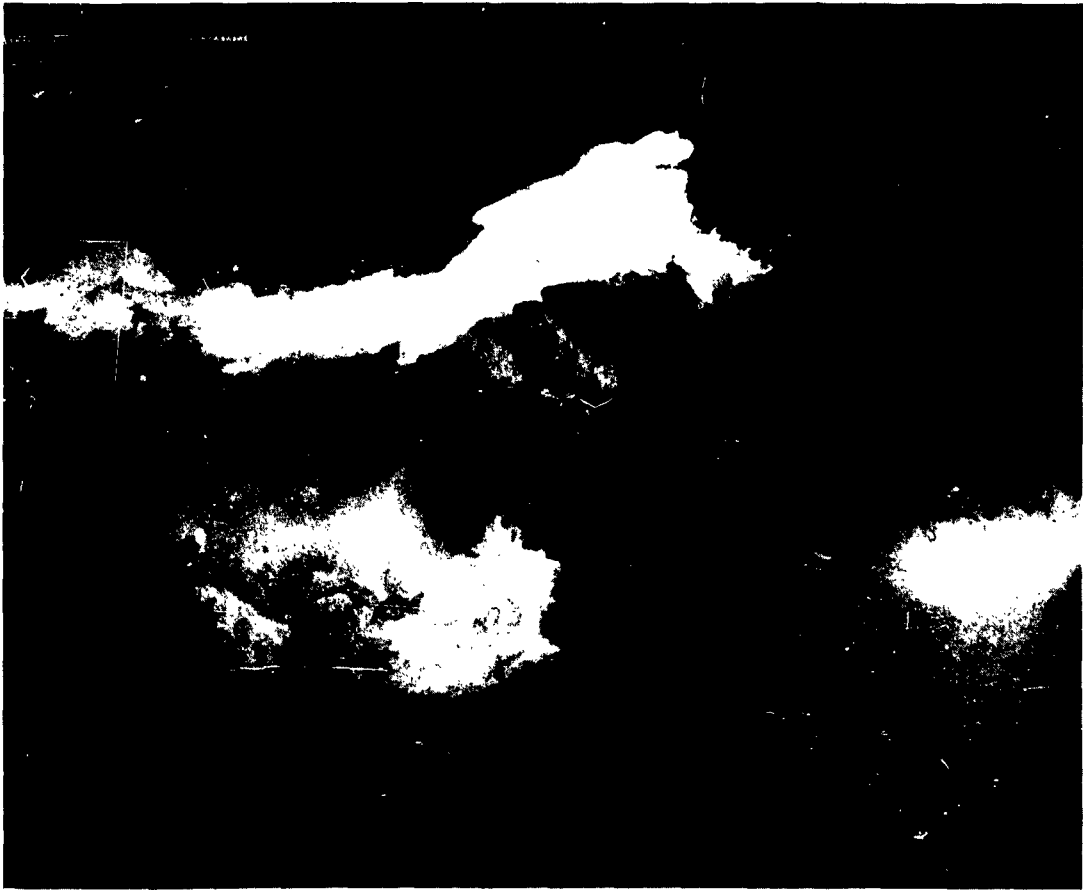


FIGURE 12. POLYETHYLENE CONTAINER AFTER NITROGLYCERIN HAS
DETONATED WITH HIGH ORDER

CONCLUSIONS AND FUTURE WORK

It was found that medium-density polyethylene is an ideal material to use to fabricate explosive safety containers. A container, 10 cm in diameter, can easily withstand the explosion of 15 g of nitroglycerin and a 32-cm-diameter container, 500 g of nitroglycerin.

The hand-carried 10-cm-diameter container deforms slightly with the explosion of 15 g of nitroglycerin.

The "critical" diameter for low-order nitroglycerin in explosions initiated by S-67 Du Pont squibs was found to be 12.5 mm.

Some pressure measurements on the container walls, during the explosion, will be made in order to obtain information on the pressure shock acting on the user's hand. To protect personnel synthesizing hazardous material, the equipment needed for synthesis will be coated with polyethylene.

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<p>Naval Propellant Plant, Indian Head, Maryland (NavWeps 8030)</p> <p>SOME CONSIDERATIONS ON PLASTIC MATERIALS FOR USE AS SAFETY CONTAINERS. By Martin F. Zimmer and Leo K. Asaoka. (TR 130)</p> <p>15 April 1963. 21 pp.</p> <p>Developmental studies were made with polyurethane containers. The effects of material properties, shape and size of both inner vials and containers, and the shock attenuation of</p> <p>(over)</p>	<p>UNCLASSIFIED</p> <ol style="list-style-type: none"> 1. Containers 2. Polyethylenes - Uses 3. Polyurethanes - Uses 4. Safety equipment. <p>I. Zimmer, Martin F. II. Asaoka, Leo K.</p> <p>UNCLASSIFIED</p>	<p>Naval Propellant Plant, Indian Head, Maryland (NavWeps 8030)</p> <p>SOME CONSIDERATIONS ON PLASTIC MATERIALS FOR USE AS SAFETY CONTAINERS. By Martin F. Zimmer and Leo K. Asaoka. (TR 130)</p> <p>15 April 1963. 21 pp.</p> <p>Developmental studies were made with polyurethane containers. The effects of material properties, shape and size of both inner vials and containers, and the shock attenuation of</p> <p>(over)</p>	<p>UNCLASSIFIED</p> <ol style="list-style-type: none"> 1. Containers 2. Polyethylenes - Uses 3. Polyurethanes - Uses 4. Safety equipment. <p>I. Zimmer, Martin F. II. Asaoka, Leo K.</p> <p>UNCLASSIFIED</p>
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<p>the container material were investigated. Various materials were evaluated as possible candidates for fabricating the containers.</p> <p>Polyethylene containers, to safely hold comparatively large loads of explosive materials, have been developed and investigated. A 10-cm-diameter container can easily withstand the explosion of 15 g of nitroglycerin, and a 32-cm-diameter container can withstand an explosion of 500 g of nitroglycerin.</p>		<p>the container material were investigated. Various materials were evaluated as possible candidates for fabricating the containers.</p> <p>Polyethylene containers, to safely hold comparatively large loads of explosive materials, have been developed and investigated. A 10-cm-diameter container can easily withstand the explosion of 15 g of nitroglycerin, and a 32-cm-diameter container can withstand an explosion of 500 g of nitroglycerin.</p>	
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